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DISEASES CAUSED BY WATER CONTACT

by

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Diseases associated with water contact are reviewed with respect to the sources of etiological agents, the types of diseases and the conditions under which they occur. The sources of disease agents fall into three general groups; point sources such as sewage treatment plants; dispersed sources related to animal wastes; and the water environment itself. Diseases associated with bacteria indigenous to the water environment were notable because exposed individuals who became ill were invariably compromised in some way. Risk of disease due to point sources of pollution can be minimized through sewage treatment and disinfection, whereas risk of disease due to animal contamination or bacteria native to water environments can be minimized only by avoiding exposure situations and by public health education measures.

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I. INTRODUCTION

Water contact recreation is one of the most popular leisure time activities in the United States. These activities may take the form of swimming, surfing, scuba diving and water-skiing, wherein there is prolonged contact with the water, or boating and fishing, wherein there is minimal water contact. Water-associated health risks from indigenous or introducted microbes will vary according to the type of activity, but it can be reasonably assumed that swimming, surfing, scuba diving and water-skiing present a greater risk than either boating or fishing because of the potential for prolonged intimate contact with the water and the greater likelihood of ingesting the water. The risks also will vary with the quality of the water, as there is a much greater risk from contact with water that has been contaminated with domestic wastewaters discharged from sewage treatment facilities.

The risks of illness from water contact activities can be segregated into two groups depending on the type of water exposure: (1) exposure to water which contains microorganisms introduced to the environment via sewage treatment plant outfalls and nonpoint sources of human and animal wastes and (2) exposure to water which contains microorganisms indigenous to the aquatic environment. Pathogens associated with enteric infections are usually transmitted by exposure to water contaminated by human or animal wastes. The epitome of this type of infection is typhoid fever, which is caused by Salmonella typhosa from human wastes. Leptospirosis is not an enteric infection but is also generally transmitted through contact with waters contaminated by animal and human wastes. Water which has not been contaminated by human or animal fecal wastes contains microorganisms indigenous to the aquatic environment, and although these bacteria are normally harmless, under certain conditions they may be hazardous to individuals who come in contact with them.

The untoward conditions occur when an individual whose body defense mechanisms have been compromised, either by a break in the integrity of the skin or because of the use of immunosuppressive agents, or because of unnatural tissue stresses caused by accidental events, such as a near drowning. Vibrio parahaemolyticus is a good example of a bacterial species capable of causing infection in individuals with weakened body defense mechanisms. Vibrio species are usually not pathogenic for healthy individuals who swim in water containing relatively high densities of this organism. The risk of illness or infection from indigenous aquatic organisms is usually increased by the presence of organic industrial and domestic wastes which causes bacterial growth to occur. Under these conditions the organisms can easily reach densities far above ambient levels, thereby increasing the probability of exposure.

Epidemiological studies of selected populations exposed to water contaminated with sewage treatment plant discharges have provided the primary evidence associating disease with water contact activities, especially swimming and water quality. Outbreaks have provided additional evidence associating disease in a group of individuals with a common water contact exposure. Reports of sporadic cases of disease associated with water contact are another source of information which help to define relationships between illness and exposure to surface waters.

This chapter will examine the various categories of disease associated with water contact and attempt to define the relationship between pathogens, the water environment, and the water-associated health risks of these pathogens.

II. DISEASE AND INFECTIONS CAUSED BY WATER CONTACT

A. Typhoid Fever and Salmonellosis

Typhoid fever was one of the earliest reported diseases to be associated with water contact. Discher[1] reported on an outbreak of typhoid fever in 1888 where 49 cases were found to be associated with swimming in the Elbe River in Germany and another in 1892 which affected ten soldiers who had bathed in the Danube River. About two decades later Reece[2] reported an outbreak of typhoid fever in Walmer, England among marine recruits who swam in a seawater filled pool as a part of their training. The pool, which was filled by opening gates on an incoming tide, had been contaminated with effluents discharged from nearby sewage outfalls. Twenty of 34 typhoid cases were attributed to swimming in the pool.

Ciampolini[3] reported on the probable cause of typhoid fever cases which occurred in the City of New Haven, Connecticut in 1923. This frequently quoted report did not establish a direct relationship between these cases of typhoid and bathing in the grossly polluted water of New Haven harbor, but circumstantial evidence was presented which indicated that swimming in the harbor may have been one of the means of transmission. Swimming activity was suspected for a number of reasons. First, the health center district, which included the harbor area, had a much higher incidence of typhoid than the City of New Haven as a whole. Second, food, milk and drinking water were ruled out as sources of infection. Lastly, 10 of the 32 cases from the health center district had been swimming in the harbor. Although the evidence is not strong, it is reasonable to assume that the harbor water contained S. typhosa, since Winslow and Moxon[4] reported at a later date that the coliform density in harbor water samples was extremely high. A report[5] published by the City of New York

Department of Health in 1932 presented conclusions similar to those of Ciampolini. According to the report, it was probable that an unusual increase in the number of cases of typhoid fever was due to bathing in polluted harbor waters. Milk and drinking water were ruled out as possible common sources for the pathogen. As in Ciampolini's report, direct evidence relating water contact to typhoid fever was not presented, but the elimination of other potential sources of disease suggested that swimming activity was the likely source of the infections.

In 1947 Martin[6] reported an interesting series of cases of paratyphoid fever which occurred in individuals who used a bathing pool on the Waverly River in Beccles, Suffolk, England. Bacteriophage typing of pathogens from infected individuals who had swam in the pool had the same phagetype as S. paratyphi isolated from water samples collected upstream and downstream from the pool. A survey of homes in the vicinity of the river revealed that a building upstream from the pool was discharging fecal wastes directly into the stream. Two healthy carriers of S. paratyphi were found among the users of the building's wastewater system. The phagetype of S. paratyphi isolated from the carriers was the same as that of Salmonella strains isolated from the infected swimmers. This study is unique among the early disease outbreak reports because it clearly established the source of the pathogen, the role of water in the transmission of the disease and the etiologic agent in the infected swimmers.

The most recent outbreak of swimming-associated typhoid fever occurred in Western Australia in 1958.[7] Ten of 15 cases of typhoid

were attributed to swimming at a city beach, which was occasionally contaminated with high concentrations of fecal coliforms. The evidence associating the disease with swimming was considered marginal because a common source of the pathogens, such as a carrier, was not identified. Multiple phage types were noted among the Salmonella typhi strains isolated from patients and this led observers to assume that the "mixed bag" of Salmonellae must have originated in sewage rather than from a common source.

Swimming-associated disease outbreaks caused by Salmonella species have not been reported since the Australian outbreak. The infrequent occurrence of typhoid and salmonellosis among bathers in the last twenty to thirty years is similar to the observed decrease in the overall incidence of these diseases. Olivieri[8] has shown the dramatic decrease in typhoid fever between 1880 and 1980, and there has been a similar decrease in waterborne and foodborne typhoid fever during this same period. Many factors, such as the use of chlorine to disinfect drinking water and wastewater, increased attention to personal hygiene, the use of antibiotics, the pasteurization of milk and careful food processing, probably have contributed to the decreasing incidence of typhoid fever and salmonellosis.

B. Shigellosis

Shigella gastroenteritis has seldom been associated with swimming in polluted water, in spite of the fact that only 10 to 100 bacilli are required for an infectious dose.[9] The paucity of swimming-associated disease outbreaks caused by Shigella is probably due to the fact that they do not survive for long periods in aquatic environments.[10] Only one outbreak of swimming-associated shigellosis

has been reported in recent years. In 1974 in Dubuque, Iowa, 31 of 45 cases of shigellosis were found to be associated with swimming in the Mississippi River.[11] Twenty-two of the cases had been swimming in the river three days prior to becoming ill and the other nine were secondary cases. The relationship between shigellosis and swimming was strengthened one because Shigellae were isolated from water where the swimming occurred. At least one strain isolated from the bathing area had the same antibiotic sensitivity pattern as strains isolated from cases in a foodborne outbreak which occurred in Dubuque at about the same time as the swimming-associated outbreak. This finding indicated that the source of the Shigella probably was a sewage treatment plant serving Dubuque and located about eight kilometers up river from the swimming area. Water samples collected along the river shortly after the outbreak were shown to have fecal coliform densities between 400 thousand and 5 million per 100 ml.

C. Viral Gastroenteritis and Hepatitis A

The association between viral illnesses and water contact in recreational waters has been tenuous because of the difficulty of isolating the etiologic agent from aquatic environments and because many viruses are unculturable. Some of the early reported outbreaks of viral illnesses described relationships between disease and exposure where the linkage to viruses was somewhat ambiguous. Such was the case in a 1969 outbreak of hepatitis A attributed to swimming exposure.[12] The outbreak occurred among members of a boy scout troop camping at an island recreation area in South Carolina. Fourteen scouts developed hepatitis A. The clustering of cases suggested that

lake water was the common source of the exposure. There was some question, however, about whether lake water was swallowed while swimming or inadvertently consumed from containers used to hold lake water for dousing fires. The accidental drinking of lake water from these containers appeared to be the most plausible source, since only lake water from outside the swimming area exhibited evidence of fecal contamination. Another outbreak, possibly associated with swimming activity occurred at a boy's summer camp in Vermont in 1972.[13] Coxsackie B virus was identified as the etiologic agent of the outbreak. The virus also was isolated from a sample of lake water, which implied that swimming was a possible means of transmission of the pathogen. However, there was a strong clustering of infections among groups of boys living in the same cabins and this suggested that person-to-person spread of the virus may have been the more important principal means of transmission. The study presented insufficient data to clearly establish swimming as the means of transmission of the enteroviruses.

There was less ambiquity about the cause of an outbreak of gastrointestinal illnesses at a recreational park in Michigan in 1979.[14] An epidemiological investigation indicated that illnesses were positively associated with swimming activity and serologic studies identified Norwalk virus as the etiologic agent. Although the means of transmission of the virus was clearly identified, the source of the contamination of the lake could not be determined. Water samples collected before and after the outbreak indicated that the microbial quality of the water was within the currently accepted limit established by the Environmental Protection Agency as accept-

able for recreational contact water. Although this finding did not contradict the association between illness and swimming activity, it did leave open the question, "What was the source of the virus?" This above question was answered, however, in one reported swimming-associated outbreak of viral gastroenteritis in Niort, France, where Coxsackie A virus was isolated not only from stool specimens of cases but also from a lake water sample.[15] The lake water samples contained Escherichia coli at densities between 50 and 1000 per 100 ml, indicating fecal contamination by humans or other warm-blooded animals. This outbreak in France appears to establish to a greater extent than other reported outbreaks the linkage between viruses in water and enteritis associated with water contact.

Waterborne disease outbreaks are usually identified because illnesses, which occur among individuals who have something in common, are clustered spatially or temporally. Since they occur sporadically and without warning, it is often impossible to obtain information that would be useful for associating illness with water contact. Epidemiological studies such as conducted in Madison, Wisconsin in 1977[16] are able to overcome some of these shortcomings. This study was designed to test the hypothesis that swimmers contaminate the water they use and that viruses are transmitted by recreational water. A sample population of children under 16 years of age who visited a pediatric clinic submitted clinical specimens for enterovirus analysis and were questioned about the frequency and location of swimming in the two weeks prior to the clinic visit. Two-hundred and ninety-six children with enteroviral-like syndromes and 679 children with no symptoms participated in the study, and non-polio

enteroviruses were isolated from about half of the ill children. Enteroviruses that were isolated included Coxsackie A and B viruses, Echoviruses, Adenoviruses and viruses listed as untypable or unidentifiable. Children who reported swimming exclusively at beaches had a much higher risk of enteroviral illness than those children who reported no swimming activity. Children who reported swimming exclusively in pools had no increased risk of enteroviral illness. There was no difference in the reported swimming exposure during the two weeks prior to the clinic visit between the children who had symptoms and no virus isolated, and the children who were not ill or had no symptoms. The results of the study appeared to confirm that enteric viruses are transmitted from swimmer to swimmer by bathing water, however, it was impossible to identify the exact route of exposure because swimmers were defined only as individuals who visited the beach and no distinction was made between those who immersed their bodies in the water and those who did not. It is possible that person-to-person contact could have accounted for some of the illness in the group of children classified as swimmers, especially in those who did not immerse their bodies in the water, and this would tend to reduce the observed relationship between illness and swimming. Person-to-person transmission was ruled out since no illnesses were observed in pool swimmers where water transmission was effectively eliminated because the pool water was sufficiently chlorinated to keep enteroviral concentrations very low.

Prospective epidemiologic studies have also been used to identify the relationship between viral gastroenteritis and water contact. The U.S. Environmental Protection Agency conducted a series of

ten studies at marine and fresh water bathing beaches, to obtain information on the possible relationship between swimming-associated health effects and the quality of bathing water.[17] Symptomatic illness in swimmers and beach going nonswimmers was determined by telephone interview eight to ten days after a swimming exposure. The symptoms were placed in four categories; gastrointestinal, respiratory, eye and ear, and "other". Swimmers used waters which ranged from barely acceptable by local standards and to relatively unpolluted bathing waters, and this provided possible exposures to determine if there was a relationship between sewage-contaminated water and swimming-associated illness. Gastrointestinal illness was found to be associated with swimming and was directly related to water quality whereas respiratory illness, ear and eye infections and "other" symptoms were not related to water quality. These findings were not unexpected, since it is reasonable to assume that water contaminated with domestic sewage effluents play a significant role in the transmission of gastrointestinal disease. Swimmers generally described their illnesses as a mild, acute gastroenteritis of short duration characterized by diarrhea, vomiting, nausea, stomachache and fever. Some of the study participants had severe symptoms and either stayed home, stayed in bed or consulted a physician. The incubation period ranged between 24 and 48 hours, and the disease manifestations lasted for 24 to 72 hours. The illness usually cleared spontaneously, without sequelae. The symptoms of illness were nearly identical with those usually described for Norwalk Agent, rotavirus and other similar viruses.[18] The rapid onset and the short duration of symptoms are unlike those of bacterial gastro-

enteritis which usually occur after a longer incubation period and usually are of longer duration. Although the etiological agent of swimming-associated gastroenteritis was not determined, similar results were obtained in several studies at different times and places. This consistency leaves little doubt as to the association between gastrointestinal illness and swimming, and swimming and the observed increase in swimming-associated gastroenteritis in waters with higher levels of pollution.

D. Ear Infections

Otitis externa is an inflammatory condition of the skin of the external auditory canal. This type of infection is so frequent among swimmers that it is commonly called "swimmer's ear". The infection is characterized by swelling, redness and pain. Otitis externa is frequently associated with hot and humid weather, maceration of tissues in the ear canal and trauma to ear tissues.[19] Other factors which influence the occurrence of ear infections are age and the time spent in the water. Individuals less than 18 years old and persons who spend long periods of time in the water are more likely to contract "swimmer's ear".[20] Swimming-associated ear infections are most frequently caused by Pseudomonas aeruginosa,[21] however, many other Gram-negative bacteria, as well as a few Gram-positive orgaisms such as staphylococci and streptococci, have also been identified as the etiologic agent of otitis externa in swimmers.

The association of ear infections with swimming activity has been confirmed through the use of epidemiological studies. Hoadley and Knight[22] in 1975 conducted a survey of 244 individuals in the area around Jackson Lake, Georgia, and found through physicians

that earaches were five times more likely in swimmers than in nonswimmers. The isolation of P. aeruginosa from the ear of those individuals with earaches was also associated with swimming activity. Calderon and Mood[23] conducted a similar survey of individuals who swam in lakes and pools, and also found that the proportion of swimmers among individuals with earaches was significantly higher than the proportion of swimmers among individuals without earaches. P. aeruginosa also was related to otitis externa infections in freshwater swimmers in a study conducted by Seyfried and Cook.[24] Pseudomonads isolated from cases were found to have the same phage and serotypes as strains isolated from bathing water samples. These studies[22-24] have clearly established the association between otitis externa and swimming in freshwater and the role of P. aeruginosa as the etiologic agent. In recent years another group of bacteria have been reported as causing ear infections in marine swimmers. Table 1 lists the halophilic Vibrio species isolated from the ears of individuals who had been swimming in marine waters. Armstrong et al.[25] isolated V. parahaemolyticus from the infected ear of a 57-year-old fisherman. An underlying factor in this case was a perforated tympanic membrane, a compromising situation also noted by Olsen[26] in a 7-year-old boy who contracted otitis media after bathing in seawater. The discharge from the boy's ear yielded a pure culture of V. parahaemolyticus. Ghosh and Bowen,[27] in Australia, also reported a case of otitis externa which was associated with V. parahaemolyticus and which occurred after a seawater contact. Other Vibrios also have been linked to swimming-associated ear infections. Vibrio alginolyticus was the causal organism in six cases of otitis externa

and four cases of otitis media reported by Ghosh and Bowen.[27] Pien et al.[28] isolated V. alginolyticus from the draining outer ears of three swimmers and Ryan[29] described a case of otitis externa in a 32-year-old man which was attributed to seawater contact. A perforated tympanic membrane, which occurred during sea bathing, was a contributing factor in a case of otitis media reported by Olsen.[26] Two other Vibrio species have been isolated from the ears of individuals with otitis externa. Armstrong et al.[25] reported an ear infection in an eight-year-old girl who had a perforated tympanic membrane. Vibrio vulnificus was the only organism isolated from the ear. Vibrio mimicus was reported by Shandera et al.[30] as the causative organism in two cases of ear infections. The age range of cases of ear infections caused by Vibrio species was seven years of age to 57 years old. Seventy-seven percent of the cases were less than 20 years old. Calderon and Mood[23] and Seyfried and Cook[24] also found that younger individuals, those under the age of twenty, were more at risk for swimming-associated ear infections caused by Pseudomonads, than other age groups.

Numerous investigators have shown that warm weather and high humidity conditions are significantly associated with the incidence of "swimmers ear" caused by Pseudomonas species. Ear infections caused by Vibrio species also appear to be related to warm weather conditions. This relationship may be due to the high densities that Vibrio species reach in coastal water environments during the warm weather season.[31] In addition, more individuals tend to go to the beach and remain in the water for long periods of time during warm weather periods.

E. Mycobacteriosis

Water contact infections due to mycobacteria other than Mycobacterium tuberculosis usually are associated with sea or brackish waters, although freshwater infections do occur. It is characteristic of mycobacterial infections that they are associated with injuries which occur during swimming activity or near the time of water contact. The extremities are the most common sites of the infections, and the hands and knees are most frequently affected. The injury to these sites is usually an abrasion, laceration or puncture wound. The lesions are of three types: (1) self-limited verrucous lesion may be observed; (2) an ulcerative skin lesion which forms a granuloma in the subcutaneous tissues; (3) an infection involving more deep-seated lesions, which form sporotricoid nodules or cause tensynovitis, bursitis, arthritis and osteomyelitis. The causative agent of these infections is invariably Mycobacterium marinum, which also is referred to in the literature under the names Mycobacterium balnei or Mycobacterium platy. M. marinum has been so closely identified with the aquatic activities of humans, such as swimming, diving, fishing and boating, that Feldman et al.[32] have dubbed this species, "the leisure-time pathogen". The infections caused by M. marinum in pools are so characteristic that they are commonly called "swimming pool" granulomas. The "swimming pool" designation, however, is a misnomer, since the infections are frequently associated with natural bathing waters, both salt and fresh.

Although the vast majority of water contact infections are caused by M. marinum, other mycobacterial species, such as M. kansasii and M. szulgai occasionally cause skin lesions much like that

of M. marinum. Cott et al.[33] reported one such case, a 36-year-old man who developed lesions on his hand about ten days after abrading it while removing barnacles from the propeller of a boat. Five months after his initial visit a new lesion, which drained a large amount of pus, appeared on his hand. The drainage material was cultured and incubated in the light and the dark. Colonies growing on the Lowenstein-Jensen medium were pigmented in both the light and the dark indicating that the organisms were scotochromogenic and a member of Runyon's Group II. The organisms, which were typically acid-fast on staining, were not speciated by the authors. Owens and McBride[34] reported isolating a photochromogenic, acid-fast bacterium from lesions on the left hand and arm of a 16-year-old male. The bacterium was identified as M. kansasii based on its maximum growth rate at 37°C. Feldman et al.[32] examined the isolate some years later and identified it as M. marinum, causing some ambiguity about the ability of the M. kansasii to cause skin lesions.

Some of the salient features of M. marinum infections are shown in Table 2. With few exceptions, M. marinum infections are associated with some event which compromises the integrity of the skin. Lacerations and abrasions occur most frequently on the foot, hand, knee and elbow, and these are the sites where infections are likely to be seen. Animal bites and puncture wounds from fish or shrimp fins occur less frequently, but infections at these sites are well-documented in the literature. The median age of the 34 reported infections was approximately 36 years old, which reflects the activities usually associated with aquatic injuries, i.e., boating and fishing. In fact, in some areas M. marinum infections are considered

an occupational hazard among commercial fisherman. An interesting feature of M. marinum infections is the long duration between the actual infection event and the diagnosis of the causative organism. Although the lesions are usually tender, they are not painful, and therefore, they may be ignored for long periods. Although the duration of illness in the reported cases ranged from two weeks to 27 years, most infections if left untended will heal spontaneously within a few years.

F. Pneumonia

The density of potential pathogens in natural surface waters is usually not high enough to create a health hazard even if an aerosol is created which might be inhaled by a susceptible individual. Similarly, under normal circumstances, seldom is enough water swallowed so that accidental aspiration of water into the bronchial tree would pose a health risk. There is, however, a circumstance wherein the risk for pneumonia has been shown to be high. Near-drowning episodes, especially in individuals over the age of 35 years old, clearly are related to cases of pneumonia. Table 3 lists six cases of pneumonia related to water contact. Four of the cases were associated with near-drowing incidents, one was related to a boating accident and the fifth case occurred in a navy diver who died from acute bronchopneumonia following a diving exercise.

Two of these pneumonia cases were observed after seawater contact. A 56-year-old man was admitted to the hospital after a near-drowning accident.[35] On the third day after admittance, the patient appeared to recover, but a day later he had a relapse. After antibiotic treatment the patient recovered. Pseudomonas putrefacians and

Staphylococcus aureus were isolated from sputum specimens, but the latter was recovered only from initial specimens, whereas P. putrefaciens continued to be isolated up to day 24. The second case was a 13-year-old boy who was resuscitated after being submersed in a tidal marsh for about eight minutes.[36] Following admission to the hospital, the boy developed cardiac and respiratory failure. A. hydrophila was isolated from blood and sputum samples. The patient recovered after treatment.

Pneumoniae attributed to A. hydrophila was observed in another near-drowning victim, a 34-year-old construction worker who fell off a truck into a drainage ditch face down.[36] Twenty-four hours after he was admitted to the hospital, the worker suffered a respiratory distress. A. hydrophila which had antibiotic sensitivities similar to A. hydrophila isolated from drainage ditch samples was cultured from sputum samples. Another near-drowning freshwater incident, which resulted in a pneumonia, was reported from Canada.[37] Legionella pneumophila was identified as the causative pathogen after noting greater than four-fold increases in titer between acute and convalescent sera. The 48-year-old woman recovered after treatment.

Two cases of pneumonia caused by Legionella bozemanii transmitted via water have been reported in the literature.[38] One case, a navy diver who contracted pneumoinia after a training exercise, was identified as legionellosis many years after the incident. Retrospective examination of the preserved organism, which had been isolated from lung tissue with techniques used for rickettsia, indicated that it was related to Legionnaires' Disease Bacillus. Shortly afterward it was identified as a new species called L.

bozemanii. A second case involved a 60-year-old man who had been thrown from a boat into dirty, swampy water where he remained for 15 or 20 minutes before being rescued. The near-drowning resulted in a severe pneumonia that culminated in death. L. bozemanii was identified as the causative organism.

The etiologic agents of the cases described above are commonly found in the aquatic environment. P. putrefacians, for instance, was isolated from water samples collected at other ocean bathing beaches near where the victim almost drowned. Aeromonas and Legionella species are ubiquitous in freshwater environments.[39,40] Aeromonads are especially sensitive to the trophic state of lakes and ponds and therefore, this organism can be found in very high densities in waters that are contaminated by humans. Such high densities greatly increase the risk of infection in individuals whose pulmonary tissues are subjected to the unnatural insult that results from a near-drowning incident. An obvious conclusion is that the risk for respiratory infection in waters used for recreational purposes is related not only to the quality of the water, but also to the type of exposure. As a body of water becomes more polluted, the chances also increase for pneumonia to result from an accidental immersion of the body where the lungs come in contact with the water.

G. Septicemias

The invasion of the bloodstream of man by organisms that produce characteristic symptoms is commonly referred to as septicemia. Nineteen cases of septicemia occurring as a result of water contact are listed in Table 4; the etiologic agents include A. hydrophila, Chromobacterium violaceum, V. vulnificus, V. parahaemolyticus and V.

alginolyticus.

A. hydrophila usually is not associated with septicemia conditions, rather it is more likely to be isolated from wounds or even from stool specimens from cases of gastroenteritis. Most of the cases of septicemia caused by A. hydrophila have three factors in common. First, the site of entry is usually through a break in the integrity of the skin caused by an insect bite, a cut on the upper or lower extremities, or a laceration. Second, individuals are directly exposed to water or cold-blooded animals that are found in those waters. Third, and perhaps most important, the body defense mechanisms in the exposed individuals are usually compromised in some way. For instance, typical underlying diseases may be leukemia, diabetes or aplastic anemia. Most of the reported cases involve individuals over the age of 60. Only one of the five cases described by Wolfe et al.[41] was under the age of 63 and only one case was not compromised. All of the cases were associated with water exposure either through fishing or accidental immersion. Ampel and Peter[42] reported a case of Aeromonas septicemia associated with a 70-year-old man who was extensively burned in a boathouse fire and subsequently immersed his body in an adjacent pond. The incident resulted in second degree burns on 40 percent of his body. Subsequent blood cultures grew A. hydrophila. The authors suggested that the septicemia resulted from exposure to the pond water containing A. hydrophila which gained access to the bloodstream through colonization of the burn injury. Tapper et al.[43] also reported a case of Aeromonas septicemia. The patient was a 19-year-old youth who had acute myelomonogtic leukemia. The infection leading to septicemia followed

contamination of a mosquito bite by stagnant water. Four of the seven cases shown in Table 4 succumbed to the infection.

Chromobacterium violaceum is a saprophyte that is commonly in found soil and water. Most of the cases of septicemic disease in humans have occurred in the southeastern United States. Only three cases have been associated with water contact. Two of the cases reported by Macher et al.[44] involved a near-drowning and scuba diving. The near-drowning victim had inhaled and swallowed an overwhelming innoculum of C. violaceum in an accident which occurred on a Florida river. The second victim was a 28-year-old male who had a chronic granulomatous disease. Six days after scuba diving he complained about malaise and fever. Multiple dark pustular cutaneous lesions with erythematous margins developed on his buttocks. Blood cultures were positive for C. violaceum. Another case of C. violaceum septicemia associated with a near-drowning incident was reported by Starr et al.[45] The 53-year-old male victim complained of fever, malaise, myalgia and abdominal pain. The fever was persistent and apustular rash developed over his body. Blood cultures showed luxuriant growth of C. violaceum. Except in the case of the scuba diver, who had an underlying disease which facilitated the entry of the organism into the blood stream, the portal of entry for the other two cases was probably the lungs, which had been subjected to large amounts of water. This insult to the lung tissue probably provided a site where C. violaceum entered the blood stream.

Vibrio species, especially V. vulnificus, frequently have been associated with septicemia. Two characteristics of Vibrio infections is their rapid onset and the high case fatality rate. Individuals

with underlying disease appear to be more susceptible than healthy persons. The incubation period is very short and symptoms usually occur in about 16 hours. V. vulnificus was first described in 1976, although it had been reported many times before that date as the "lactose positive" Vibrio. A majority of the cases of fulminating septicemia caused by Vibrio species are due to V. vulnificus, however, V. parahaemolyticus and V. alginolyticus also have been reported as etiologic agents. The five cases of V. vulnificus septicemia and the one case of V. parahaemolyticus septicemia reported by Bonner et al.[46] were associated with underlying illnesses. Two of the cases had cirrhosis, two had leukemia, one had diabetes and another had hemochromatosis. The organisms gained entry to the body through puncture wounds in two cases, lacerated extremities in two cases, a cut on the hand in one of the cases and an ulcer in one case. All of these wounds and the ulcer were exposed to seawater, usually at the time the wound was obtained. Similar cases were reported by Castillo et al.[47] One was a 68-year-old man who punctured his hand handling an uncooked shrimp and the other was a 79-year-old man who punctured his hand with an uncooked crab claw. Both of these individuals exhibited the rapid onset of symptoms characteristic of this organism. Only the former case had an underlying disease. He had an active case of chronic hepatitis for at least three years before the Vibrio infection. The case of septicemia caused by V. alginolyticus, reported by English and Lindberg,[48] was associated with extensive burn injury suffered by a 37-year-old woman in a boating accident. The burn injury was sustained when gasoline fumes ignited in a boat. The individual was immersed in

the water to extinguish the flames during the rescue operation. V. alginolyticus was cultured from the blood as well as from biopsy material from the burn areas. Five of the nine cases of Vibrio septicemia shown in Table 4 succumbed to the infection. This high case fatality rate may be related to age as well as the underlying disease that was present in most of the cases. The median age of all of the Vibrio cases was 60 years old, a period of life when the bodies immune defense mechanisms are declining.

H. Wound Infections

Skin infections associated with water contact frequently have been reported in the literature. The infections invariably are related to lacerations or abrasions that came about during recreational or occupational activity usually as a result of some type of accident. Wounds incurred as a result of insect or animal bites, also have been reported as predisposing or related factors for infections that occur after water exposure. The infections usually occur in the soft tissues and are often self-limited, although some cases are much more serious and have resulted in amputation. The wound infections reported in the literature do not appear to be age related. They have been observed in children seven years old as well as in individuals as old as 75 years old. Table 5 is a summary of data reported in the literature.

Aeromonas species usually are associated with freshwater wound infections, although infections caused by aeromonads are occasionally seen in cases of seawater exposure in coastal areas. Most of the reported infections caused by aeromonads are due to A. hydrophila, however, one case has been described wherein Aeromonas sobria was

thought to be a causative pathogen. It was isolated, along with A. hydrophila, from a leg puncture wound sustained by a scuba diver.[49] Many of the reported wound infections involved accidents that occurred during the water-related activity. A case described by Smith[50] was related to a leg lacerated by a motorboat propeller and a case reported by Hanson et al.[51] was precipitated by a diving accident in a shallow lake which resulted in an extensive scalp laceration. A case reported by Fulghum et al.[52] involved a 62-year-old woman who fell down in a boat causing a crab trap to fall on her leg, producing two puncture lacerations. Other accidents reported by Katz et al.[53], Phillips et al.[54] and Rosenthal et al.[55] involved stepping on a nail while in the water, an alligator bite, a fall on a rock jetty which resulted in a leg laceration, and a knee laceration due to water skiing. The age range of the cases was from seven years old to 62 years old with three-fourths of the individiuals being 22 years old or less. The preponderance of younger individuals probably accounts for the type of injuries that were observed. Most of them were the result of athletic activities usually associated with young age groups, i.e., water skiing or diving. None of the infections resulted in death, although one of the cases died a few months after the initial infection had been cleared up, probably from a secondary infection.

Many reports of infections due to Vibrio species have been reported in the literature. V. alginolyticus and V. vulnificus are reported most frequently and V. parahaemolyticus only occasionally. Only four cases of V. parahaemolyticus infection have been reported, one by Roland,[56] one by Porres and Fuchs[57] and two by Bonner et al.[46]

The former cases involved injuries that were sustained on Narragansett Bay in Rhode Island. One injury was to a 40-year-old man who was "clamming" and the other was to a 9-year-old boy who scraped his knee on a barnacle-coated raft. The third and fourth cases are associated with a stingray wound and a laceration due to a seashell. Water associated V. alginolyticus infections have been reported more frequently. The wounds associated with V. alginolyticus infections were incurred in widely dispersed sites such as the Sea of Cortez,[58] the Pacific Ocean near Vancouver, Canada[59] and near Irvine, California,[60] on Long Island Sound,[61] and the Belgian North Sea.[62] In each case the initiation factor was either an accidental breaking of the skin's surface or a wound which had not healed. Three of the cases had an associated underlying disease which most likely predisposed the affected individual to infection. The wound infections caused by V. vulnificus are very much like those caused by V. alginolyticus. The infections are usually related to some event or accident which breaks the integrity of the skin. The events or accidents include lacerations,[63] insect bites,[64] puncture wounds,[63] crab bites[63] and scratches. Some of the victims had underlying diseases such as alcoholism, stasis ulcers, lymphocytic leukemia and diabetes. The age distribution seemed to be somewhat higher for cases of V. vulnificus infections than for that observed with V. alginolyticus infections.

V. vulnificus is also notable because wound infections due to this organism has been observed several hundred miles from coastal water in New Mexico and Oklahoma.[65] One case involved a serious scalp laceration in an individual who became disoriented and jumped

into a creek that contained brackish water. The other case was associated with an insect bite and subsequent exposure to saline water in the Great Salt Plains reservoir. V. vulnificus was not isolated from either of the water sources, although the patient isolates were able to grow in 0.4 percent and 0.2 percent sodium chloride the salinity of the creek and the reservoir respectively. These isolations point to the importance of considering halophilic vibrios among the potential pathogens in wound infections that occur after exposure to brackish waters, even in inland locations.

I. Leptospirosis

Leptospirosis, which also is known as Weil's disease or hemorrhagic jaundice, is caused by Leptospira species and is characterized by a course of headache, chills, fever, myalgia, nausea, and in some cases, neck or joint pain or pain on movement of the eyes. Swimming and water contact activities are two of the major means by which humans are exposed to this pathogen. Leptospira usually contaminate water environments via the urine of infected animals such as cattle, dogs, rats and hogs. Racoons, skunks and muskrats also are known to harbor Leptospira species. The organisms usually gain entry to the body through the skin, the integrity of which has been compromised by cuts, abrasions or maceration. The organism, if accidently swallowed or inhaled, also can penetrate the mucous membranes of the mouth or nasopharynx. Leptospira pomona, Leptospira caneiola and Leptospira icterohemorrhagia are the most common genera associated with disease in man, but other genera have also been implicated in cases of leptospirosis.

Some examples of typical leptospirosis outbreaks are given in

Table 6. Shaeffer[66] reported an outbreak of leptospirosis with an attack rate of 63 percent. A group of about 80 young adults and adolescents had been swimming at the local swimming hole fed by a stream in which dead hogs had been seen floating. Three months after the incident, sera from hogs, as well as other animals, were found to be positive for L. pomona, the same genus implicated in the outbreak.

A report of an outbreak in Jackson Hole, Wyoming was interesting because the cause of the illnesses was diagnosed 11 years after the event.[67] The late inquiry was made because at the time of the illness no human cases of leptospirosis had been reported. The fact that bovine epizootics of L. pomona were common in that part of the country was apparently ignored. Dogs or other wild animals with access to the pool in which the attack victims had been swimming, were the probable source of the agent which caused the outbreak. The cases reported by Jellison et al.[68] were part of a larger group of men who had been swimming in the Grand River near Wakpala, South Dakota. This report was interesting because it noted that one year after the outbreak, a water sample from the river was injected into a guinea pig and the animal developed a titer of 1:5000 against L. pomona 35 days later. This suggested that the animals contaminating the streams were probably part of a permanent carrier population.

Nelson et al.[69] reported an outbreak associated with the use of an irrigation canal downstream from a pasture where a herd of cattle were kept. The etiologic agent was isolated from standing water in the pasture and 21 percent of the cattle were found to be shedding Leptospira. An outbreak reported from Tennessee was the first one

in the United States involving L. interrogans.[70] Although the source of the etiologic agent was not identified, wild animals were suspected. Tjalma and Galton[71] reported on an outbreak of leptospirosis caused by L. pomona. Creeks in which young adults and children had been swimming were accessible to cows and hogs that were shown to be serologically positive for L. pomona.

The risks associated with exposure to swimming holes contaminated with urine from infected animals are almost impossible to eliminate. Reduction of the risks can be accomplished only through informing the public of the health hazards associated with swimming in water that is accessible to domestic or wild animals.

J. Primary Amebic Meningoencephalitis

Primary amebic meningoencephalitis (PAM) is an infection of the central nervous system caused by the free-living amebae Naegleria fowleri. PAM usually occurs in young adults or children who have a recent history of swimming in freshwater lakes or pools, or some other water associated activity, such as water skiing. Amebae in the water are accidently inhaled, and once in the nasal passage they penetrate the mucosa and cribiform plate. The amebae gain access to the meninges via the olfactory nerve fibers and after reaching the brain, they initiate an inflammatory response and cause damage to the tissue. The outcome of Naegleria infections are invariably fatal. Death usually occurs within 72 hours after the onset of symptoms. Headache, anorexia, fever, nausea and vomiting are the main symptoms of PAM. Vision also may be affected.

Naegleria species are free-living amoeba which are ordinarily found in water, soil and decaying vegetation.[72] Warm industrial

effluents promote the growth of Naegleria.[73] This species has also been isolated from swimming pool water[74] and tap water.[75]

Cases of PAM caused by Naegleria species have occurred worldwide. The first case was reported by Fowler and Carter[76] in 1965 from Australia. The disease has also been noted in Czechoslovakia,[77] Belgium,[78] Great Britain[79] and New Zealand.[80] In the United States cases have been reported from South Carolina,[81] Virginia,[82] Florida,[83] Texas[84] and Georgia.[85]

The age of PAM victims ranges from 8 years old to 27 years old. The young age distribution of those individuals contracting PAM is probably a behavioral component, since more young adults and children than older adults spend their leisure time pursuing swimming and other water activities. Male swimmers have a greater risk of infection than female swimmers but again this may be a behavioral component, since males have a tendency to do more swimming than females.

It is notable that most of the cases of PAM have been reported from southern states with only a few exceptions. This phenomenon is no doubt a reflection of the warm climate of these states. Naegleria species are known to survive and grow in favorable warm waters of the South, as well as in thermal industrial effluents in more northern climates.

Although PAM cases are invariably fatal, the risk of acquiring this disease is very small. Wellings[86] has estimated that only about one case of naeglerial infection will result for every 2.6 million exposures to waters containing this pathogen.

K. Shistosome dermatitis

Shistosome dermatitis, also called swimmer's itch, clam digger's

itch, cercaria dermatitis or cutaneous dermatitis is an allergic reaction due to the presence of parasitic flatworm cercariae in the skin. Migratory ducks and other waterfowl are the usual host of the adult flatworm and humans are an incidental host of this parasite. The life cycle of the shistosome begins with the production of eggs in the normal host. The eggs are excreted in the feces, usually into water, where a larvae emerges. The larvae burrow into snails, the intermediate host, where they form sporocysts. After a suitable developmental period, fork-tailed cercariae are released into the water. The cercariae settle on aquatic vegetation, which is eaten by ducks and the cycle begins again. Humans are a substitute host for the cercariae.

Shortly after the initial exposure to the cercariae, a mild itching occurs, which can last up to an hour. Ten to 12 hours later pruritic papules form. The inflammatory response reaches a peak in 3 to 4 days and then recedes during the ensuing week or two.

The cercariae do not penetrate beyond the dermis of the skin and they seldom remain alive in the substitute host for more than one or two days. Symptoms are accelerated and more severe on subsequent exposures to cercariae, but the duration of the inflamation is much shorter.

Shistosome dermatitis is endemic in Canada, Michigan, Wisconsin, Minnesota and along the Mississippi River and other flyways used by waterfowl commonly infected with the parasitic flatworms. The disease also has been observed in other areas of the United States.

In 1974 Wills et al.[87] described an outbreak of shistosome dermatitis in Pennsylvania which occurred in children who swam in a

farm pond suspected of being responsible for the source of itching sensations and red spots that developed shortly thereafter. The pond was the residence for five species of duck and geese and frequently was visited by transient water fowl, such as mallard ducks. Snails collected from the pond were found to shed high densities of shistosome cercariae which were assumed to be the cause of the dermatitis.

In 1981 16 cases of cercarial dermatitis were reported in Humbolt County, California.[88] The individuals had been swimming in a cove of the Mad River, ten miles from the Pacific coast. A search for evidence of the parasites at the site of exposure revealed snails of the genus Physa in shallow pools along the river. The snails were transported to the laboratory where cercariae were observed emerging from the snails held in dishes of water.

The disease is worldwide with shistosome dermatitis being reported from Europe, Central and South America, Mexico, Australia, New Zealand, Maylasia, India and Africa.[89]

Public health measures to prevent shistosome dermatitis include informing swimmers of the presence of infected snails and, if necessary, controlling infected snail populations through the appropriate use of molluscicides.

III. CONCLUSIONS

The infections associated with water contact fall into two distinct groups. The first group is enteric illnesses which result from the ingestion of water while swimming in fresh and marine waters which have been contaminated with effluents from sewage treatment plants. Illnesses associated with this type of exposure are similar in both marine and fresh waters and they

have a tendency to affect young rather than older individuals. The risk of illness after exposure to water contaminated with human fecal material is governed by the number of diseased individuals in the population discharging the wastes. If the number of individuals shedding pathogens is small, they then the risk of illness after contact with contaminated water will be minimal. The risk becomes greater as the size of the contributing population increases, since there is a greater probability for diseased individuals and thus a larger number of individuals shedding pathogens. The source and nature of these pathogens implies that the risk of illness can be decreased or possibly eliminated using sewage treatment technology and disinfection procedures. The second group of infections are not amenable to elimination by man-made technology, since the etiologic agents, with the exception of Letospira species, are mainly bacteria that are indigenous to the aquatic environment. These native bacteria are normally innocuous for healthy people, but they can be pathogenic under certain circumstances. The opportunistic nature of these bacteria is evident in most of the outbreaks and cases that were reviewed. During or before the water contact, an event usually occurred which compromised the host body defenses in some way, such as laceration or abrasions of the skin, puncture wounds, animal or insect bites or some underlying disease such as diabetes, leukemia or hepatic dysfunction. The infections caused by native aquatic bacteria appear to be seasonal in nature, usually occurring during the summer months. The warmer months of the year are when most water contact activity takes place, and it is during this period that the native bacteria reach their highest densities. In some cases there appears to be a regional component as seen with the infections caused by Chromobacterium species. Chromobacterium infections occur mainly in the southeastern region of the United States. The reason for this regionalization is not clear since

this organism is ubiquitous across the country.

Leptospirosis obviously does not fit either of the patterns described above. Commonly used indicators of fecal contamination will not predict risk of illness from Leptospira species in water environments since the urine of domestic and wild animals does not contain bacteria associated with feces. Leptospira does, however, have many characteristics in common with opportunistic pathogens that cause infections or illness in individuals who come in contact with water. For instance, leptospirosis is much more likely to occur in swimmers whose skin has been cut, abraded or macerated. This characteristic is not an absolute requirement for infection but it does increase the risk of infection. The seasonality of Leptospira infections also is similar to that of bacteria native to aquatic environments in that most cases of leptospirosis occur in the warm summer months. Furthermore, the population at risk tends to be the same as the one most commonly infected by bacteria indigenous to water environments. The method of dealing with health risk due to Leptospira is also similar, since educating the public as to the potential health hazards associated with swimming in certain environments is the only means of coping with this public health problem.

The etiologic agents that cause disease are not the same for fresh and marine waters. Although there is some overlap, the infections observed in marine waters are usually due to halophilic Vibrio species, whereas the freshwater infections are usually caused by Aeromonads, Pseudomonads and mycobacterial species. These differences, the ubiquitous character of most of the pathogens and their opportunistic nature are the factors which prelcude using technology to lessen the risks associated with water contact. It is only through educational means whereby users of water resources are made aware of potential health hazards and their predisposing condition, that the risks for disease be lowered.

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TABLE 1. Ear Infections Caused by *Vibrio* Species in Marine Water Swimmers

Etiologic Agent	No. of Cases	Type of Ear Infection	Median Age	Reference
V. alginolyticus	14	Otitis externa (10)[a] Otitis media (4)	<20 yrs	27,28,29
V. parahaemolyticus	4	Otitis externa (2) Otitis media (2)	20 yrs	27,25,26
V. vulnificus	1	Otitis externa	8 yrs	25
V. mimicus	2	Otitis externa (1) Otitis media (1)	26 yrs	30

[a]Number of cases

TABLE 2. Characterization of Infections Caused by *M. marinum*

No. of Cases	Method of Injury	Site of Lesion	Age Range (median)	Median Duration of Infection Before Diagnosis (Range)
15	Laceration	Foot (4)[a] Knee (3) Hand (7) Arm (1)	10-63 (19)	1 yr (3 mos - 27 yrs)
12	Abrasion	Knee (6) Hand (3) Foot (1) Neck (1) Elbow (1)	14-53 (29)	8 mo (3 mos - 6 yrs)
6	Puncture Fish Fin Shellfish	Hand (5) Ankle (1)	16-58 (52)	3 1/2 mo (2 wks - 2 yrs)
1	Dolphin Bite	Finger	19	1 yr

[a]Number of cases

TABLE 3. Predisposing Factors for Pneumonias Associated with Waterborne Pathogens

Etiological Agent	Exposure	Age	No. of Cases	Reference
Pseudomonas putrefaciens	Near Drowning[a]	56	1	35
Aeromonas hydrophila	Near Drowning[b]	35, 13	2	36
Legionella pneumophila	Near Drowning[b]	48	1	37
Legionella bozemanii	Boating & Diving Accident[b]	60, 36	2	38

[a]Saltwater
[b]Freshwater

TABLE 4. Factors Associated with Septicemic Disease that Occurs as a Result of Water Contact

Etiological Agent	No. of Cases	Median Ages	Range of Ages	No. with Predisposing Factors[a]	Reference
Aeromonas hydrophila	7	65	16-81	6	41,42,43
Chromobacterium violaceum	3	49	28-53	1	45
Vibrio vulnificus	7	60	51-79	6	46,47,48
Vibrio parahaemolyticus	1	65	-	1	46
Vibrio alginolyticus	1	37	-	-	49

[a]Typical predisposing factors are diabetes, leukemia and aplastic anemia

TABLE 5. Characteristics Associated with Skin Infections that Result from Water Contact

Etiological Agent	No. of Cases	Median Ages	Range of Ages	No. with Predisposing Factors[a]	Reference
Aeromonas sobria	1	19	-	-	49
Aeromonas hydrophila	8	19	7-62	1	49,50,51, 52,53,54, 55
Vibrio alginolyticus	7	32	22-50	3	58,59,60, 61,62
Vibrio vulnificus	20[b]	58	13-75	6	63,64,65
Vibrio parahaemolyticus	4	25	9-40	-	46,56,57

[a]Typical predisposing factors are lacerations, abrasions and insect or animal bites

[b]Age information available only for six victims

TABLE 6. Outbreaks of Leptospirosis Associated with Swimming in Fresh Water

Outbreak Location	Etiologic Agent	No. of Cases	Possible Source	Reference
Geneva, AL	*L. pomona*	50	Hogs	67
Jackson Hole, WY	*L. canicola*	24	Dogs	66
Standing Rock Indian Reservation, South Dakota	*L. pomona* *L. antumnalis*	5	Livestock	68
Kennewick, WA	*L. pomona*	61	Cattle	69
Tennessee	*L. interrogans*	7	-	70
Cedar Rapids, IA	*L. pomona*	40	Cattle	71